MEASURING CARD FOR ELECTRICAL IMPEDANCE TOMOGRAPHY V2.0

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Abstract: This project aims to improve the first version of an electrical impedance tomography card. The main enhancement of this version is the replacement of Raspberry Pi with a better platform - STM32, implementation of voltage and phase shift measurements, and error correction in the first version. The main reason for moving from Raspberry Pi to STM32 is speed, power consumption and ease of use for the end user.

Keywords: Electrical impedance tomography, MOSFET, Shift register, STM32.

1 INTRODUCTION

EIT (Electrical Impedance Tomography) EIT is a noninvasive diagnostic method for the reconstruction of impedance distribution in the measured environment. This method is based on the switching current source and voltage measurement. At the same time, the phase shift between voltage and current is measured for the individual measuring combinations. Most EIT studies only deal with the measurement of the real part of the impedance, the resistance without measuring the phase shift - the imaginary part of the impedance. For certain materials, the phase shift itself can range from 1 to 600 mrad depending on the input frequency. For this reason, it was necessary to select the correct components and at the same time guarantee their calibration. The first version of the measurement card for the EIT only included the possibility to control the switching of the current source and the voltage measurement, while the remaining measurements had to be performed on external measuring devices. To limit errors due to cable lengths and subsequent interference it was necessary to design and implement a new version of EIT measuring card, which directly involves phase shift and voltage measurement as well as calibration. The main control board of the measuring card contains the STM32 microcontroller, which ensures communication with the PC via the USB interface. This microcontroller also contains precise 12 bit ADC converters and comparators.

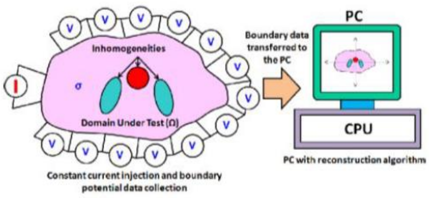

Figure 1: EIT [4]

2 REALISATION OF MEASURING CARD

The main control board provides communication with the PC, control of switching cards and measurement of voltage and phase shift. Each switching board contains 2 shift registers and 64 opto MOSFETs together with a signaling LED and 16. IO points. Individual switching boards can be chained - additional measuring layers can be added. The measuring card is powered by 12V due to type of the shift registers used. The functionality of the measuring card is described in more detail in the following subchapters.

2.1 Switching AC current with MOSFETs and internal wiring of SSR

To switch AC current, it is necessary to use a combination of two MOSFETs of type N controlled optoelectronically - fig. no. 2. The TLP3545A was used in this solution, which proved to be successful in the first version of the measuring card, as its transition area was minimal, fully galvanically separated and did not distort the switched signal. To simplify the PCB design, 12V is applied to each anode via a resistor. The cathode is connected to the shift register.

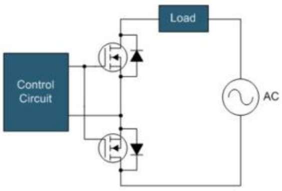

Figure 2: Solution of SSR[1]

2.2 Shift register and switching opto MOSFETs

In order to switch a larger number of opto MOSFETs, it was necessary to select a shift register that allows chaining. In this solution, the HV5530 is used, which allows switching 32 outputs to ground. This shift register has proven successful in several projects. In total, it needs only 3 control signals for control (data in, latch enable and clock). It contains data IN and data OUT for chaining more shift registers. One of the other advantages is the low consumption of 15 mA and max. clock speed 8MHz. The block of the internal connection is shown in fig. no.3.

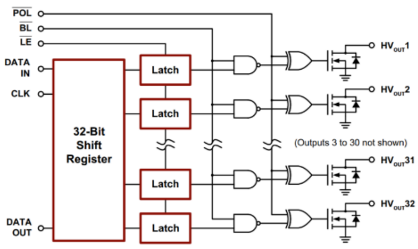

Figure 3: Internal wiring of HV5530. [3]

2.3 Measuring phase shift and voltage.

This is important information for measurements in the EIT. This connection makes it possible to measure both the real and the imaginary part of the impedance. Fig. no. 4. For measuring real component of impedance are used 12bit ADC converters in combination with a digitally controlled amplifier with adjustable gain in the range of 45dB. Comparators are used to measure the imaginary part of the impedance. For measuring voltage, it is necessary to take into note the AC voltage and its large range. In fig. no. 5. voltage and phase measurements are shown in block form.

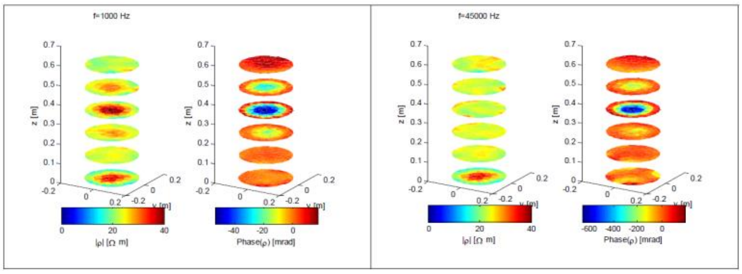

Figure 4: Display of measurement of imaginary and real part of impedance. [2]

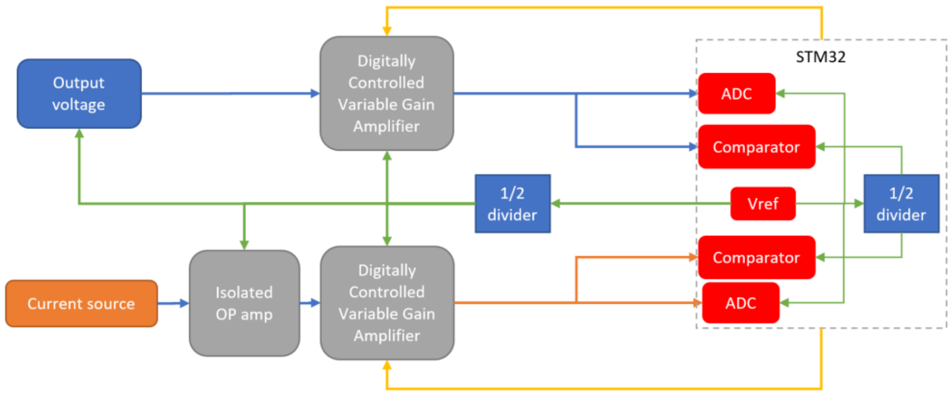

Figure 5: Measuring of phase shift and voltage.

The connection consists of the measuring branch of the current source and the output voltage. The input from the current branch is isolated from the rest of the circuit using an isolated operational amplifier. Subsequently, an operational amplifier with adjustable gain is used. A ½ reference voltage divider connected to the non-inverted input, to the inverted input of the measured voltage and output to the input of the ADC and the comparator. This connection makes it possible to shift the transition point of the 0V measured voltage to half the value of the reference source. For more accurate voltage measurement and maintenance within the ADC range, the microcontroller adjusts the required voltage gain. To detect a zero crossing, the comparator compares the measured voltage with ½ of the reference source; if it exceeds this voltage, the comparator starts the trigger. To calculate the phase shift, the microcontroller records the time from the trigger at the output voltage and current source and at the same time from the start of the measurement of the given combination of IO points. The system allows automatic calibration - when connecting a current source and output voltage to one pair of IO points and connecting a calibration resistor.

2.4 CONTROL BOARD AND COMMUNICATION WITH PC

Unlike the original control board, the STM32 microcontroller with the ARM Cortex M7 core is used in this case. It allows communication via CAN, I2C, SPI, USART and USB. Serial communication via USB is used in this application. It allows to communicate in both directions with a PC. The control system application currently works on the principle that the user selects a layer and 2 out of 16 points, which will be used to connect the current power supply, and 2 out of 16 for voltage measurement. Subsequently, the user confirms the selection and the program on the PC sends the data to the control board, which sets the switching card to the user selected IO pins. The control board will measure the value of the measured voltage and the phase against the current source. This measured data is sent back via USB to a PC, where the user can read the values.

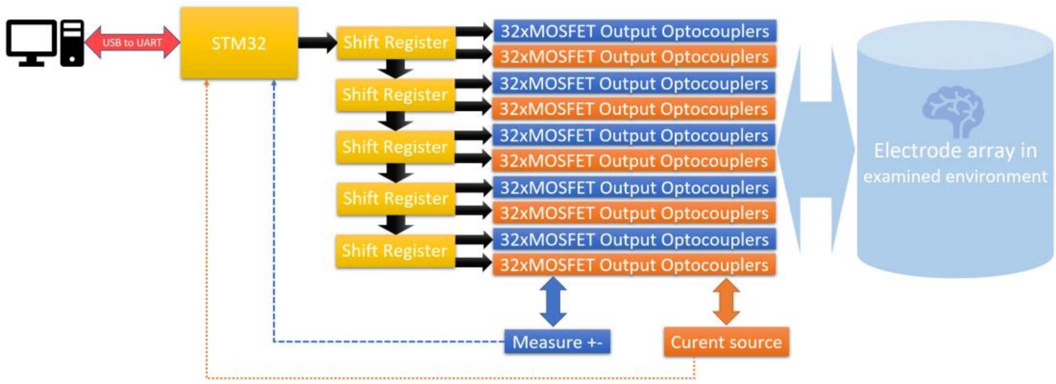

Figure 6: Block diagram of communication, control and measurement.

2.5 PARTIAL WIRING DIAGRAM.

This part of the diagram contains the connection of 16 opto MOSFETs, one shift register and 4 IO points. The overall scheme has 16 IO points, 64 opto MOSFETs and two shift registers with connections for cascading the boards and the input of the current source and voltage measurement.

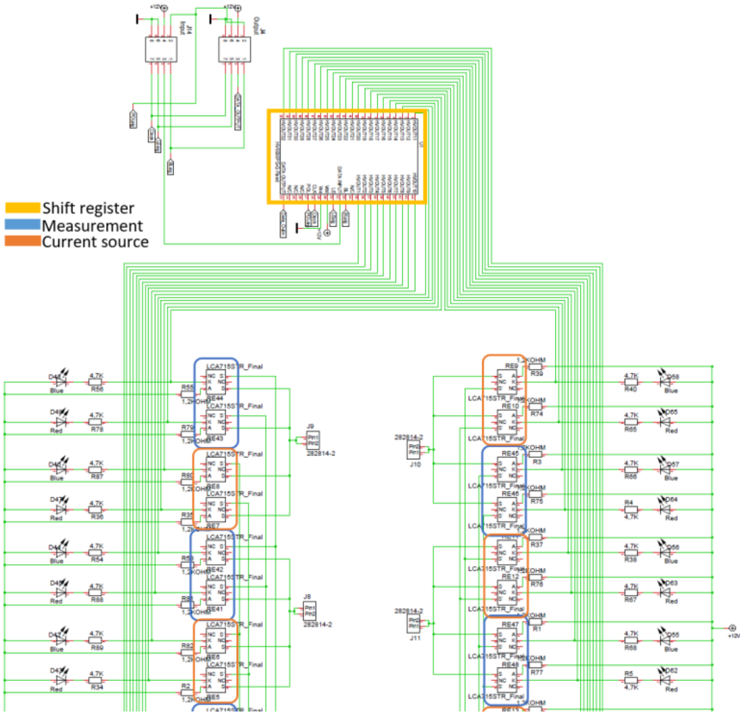

Figure 7: Partial diagram of the switching card.

3 CONCLUSION

The new version of the EIT measuring card adds the possibility to directly measure the real and imaginary part of the impedance in the measured environment, without the need to use external instruments and thus increase the comfort of measurement. At the same time, the device can be expanded as needed with additional layers - modularity.

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